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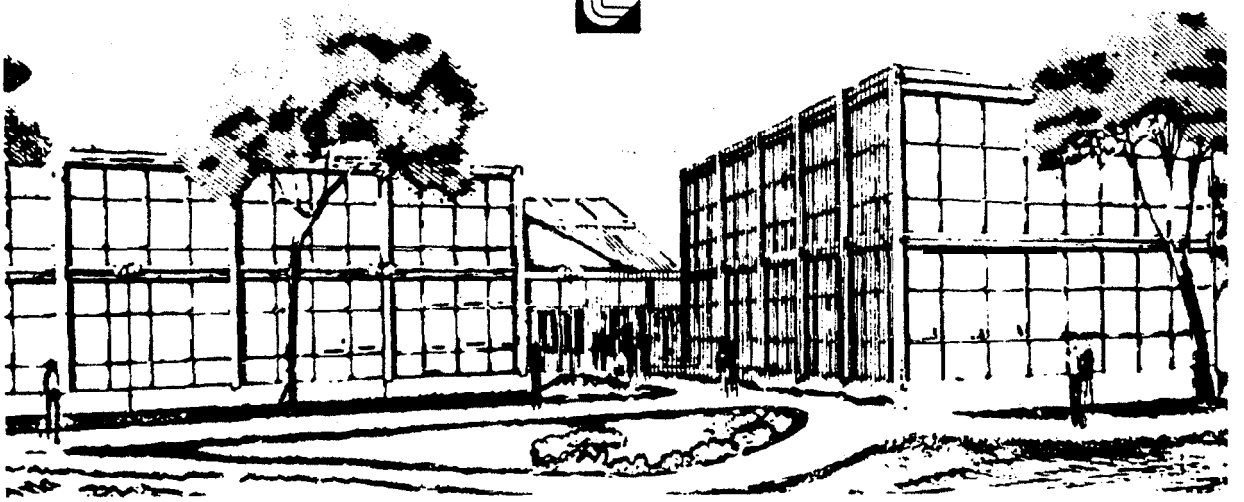

PLUTONIUM CONCENTRATIONS IN FISH AND SEAWATER FROM KWAJALEIN ATOLL

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Abstract

A **followup** *study* has been made to assess the concentrations of $^{239+240}Pu$ and ^{137}Cs in the marine environment of Kwajalein Atoll. Fish collected from the Atoll in 1972 had body burdens of plutonium that were substantially higher than concentrations in similar species from locations contaminated only with global fallout. **Our** recent results, however, indicated that Kwajalein lagoon seawater contained levels of plutonium more similar to global fallout levels found in north equatorial Pacific surface waters. No satisfactory explanation for the reported plutonium levels in fish from Kwajalein collected in 1972 could be deduced from the available data. The highest plutonium concentrations reported for the 1972 reef species of fish could expose man, through ingestion of marine foods, to a dose rate as high as 25% of 'the (3 **mrad/yr** over 70 yrs) proposed EPA guideline for annual total transuranic dose rate to bone. Our present results show the dose rate from the marine food pathway is nearer to 0.005% of the recommended EPA value and are consistent with the view that Kwajalein Atoll contains plutonium concentrations that are expected from global fallout.

The magnitude of the plutonium levels reported in fish collected from Kwajalein lagoon during 1972 was excessively high and these results appear to be inconsistent with other environmental data from the lagoon.

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Introduction

In a previous report (No 76) describing the concentrations of specific radionuclides detected in the lagoon water of Kwajalein Atoll (9°N 167°40'E), it was concluded that the concentrations of $^{239+240}Pu$ and ^{137}Cs were similar to the global fallout concentrations detected in north equatorial Pacific surface waters. However, samples of fish collected from Kwajalein Atoll in 1972 (Ne 73) contained concentrations of $^{239+240}Pu$ that were higher than levels in fish from other global regions contaminated only with global fallout debris. Another study had reported (Sc 75) that the concentrations of plutonium in convict surgeon fish collected from regions of Enewetak Atoll, one of the Pacific nuclear test sites used by the U.S. between 1948 and 1958, were not significantly different than levels in fish from the control station, Kwajalein Atoll. This was unexpected because during 1972, *1974* and 1976 the average concentration of $^{239+240}Pu$ in Enewetak lagoon water (No 78a) was 60 to 100 times higher than the 1975 average Kwajalein lagoon water concentration of 0.45 ± 0.21 pCi/m^3 (No 76). One is compelled to submit, based on these data, that the use of a concentration factor to relate plutonium concentrations in marine organisms to environmental concentrations seems highly questionable. Based on these 1972 plutonium concentration data (Ne 73) for eviscerated whole fish and the average concentration in 1975 Kwajalein lagoon seawater, the calculated concentration factors for the Kwajalein fish would range from 2×10^3 to 6×10^5. These values are orders of magnitude larger than other reported (Ne 75, No 78b, He 75, No 72) concentration factors for plutonium in fish.

The $^{239+240}Pu$ concentrations of eviscerated and whole reef fish from Enewetak Island of Kwajalein Atoll in 1972 ranged from 230-960 pCi/kg dry

(Ne 73). Eviscerated fish samples are described (Ne 73, Nev 75) as the entire fish with the gonads, gills and G.I. tract removed. The dry viscera samples from these reef fish contained an average of 430 pCi/kg of $^{239+240}Pu$. Using equations given by Wilson, et al., (Wi 75) and Robison, et al., (Ro 78), and a dietary fish intake of 600 wet gm/day, the dose rate from $^{239+240}Pu$ ingestion at these concentrations is 10-25% of the 3 mrad/yr guideline proposed by EPA (Ep 77) for annual total transuranic dose to bone. A percentage this high, resulting from a single transuranic in one Ingestion pathway is sufficient reason to warrent a re-examination of the concentrations of plutonium at Kwajalein and to resolve some of the questions raised from the previous report (No 76). Concentrations of plutonium in water, fish and sediment in recently collected samples from Kwajalein and north equatorial surface waters are discussed and compared to previously reported data.

Sample Collections and Analytical Results

During 1976, SO liter unfiltered seawater samples were obtained from lagoon locations 1, 5, 7, 8 and 10 shown in Fig. 1. Stations 1 and 5 duplicate locations sampled during 1975. Between 1975 and 1977 surface seawater samples were collected at several open ocean locations within the area of the Northern Marshall Islands. Plutonium and cesium were separated from the water samples and the concentrations of $^{239+240}Pu$ and ^{137}Cs were determined using published methods (Wo 78, Wo 71). Our analytical results are shown in Table 1 along with 1975 lagoon seawater concentrations previously reported (No 76). In a few samples where the ^{238}Pu concentrations were above our detection limits, the $^{238}Pu/^{239+240}Pu$ ratios were computed and are given in Table 1. For comparative purposes, concentrations in surface seawater samples collected in the north equatorial Pacific since 1972, from the cited references, are also compiled in Table 1. At one ocean surface station where the particulate material collected on a 1 µm filter was analyzed, the concentration of $^{239+240}Pu$ associated with the filtered material represented 13% of the total concentration in the water.

Eighteen mullet (14 female and 4 male), Crenimugil crenilabis, were collected on October 21, 1976 from the lagoon reef off Enewetak Island at Kwajalein Atoll. The standard length of the fish varied from 265 to 386 mm. Reef fish collected from this island in 1972 (Ne 73) had the highest reported plutonium body burdens at Kwajalein Atoll. Mullet are primary consumers and represent species belonging to the second trophic level. Guary and Fraizier (Gu 77) maintain that concentration factors for

plutonium in aquatic primary consumers are much higher than values established for secondary and tertiary consumers, It has also been suggested (Li 77, Bo 76) that some aquatic bottom feeders have higher body burdens of plutonium than fish that rarely feed on the bottom. Mullet indiscriminately feed by scooping up the surface benthos to 'extract organic matter from the sediments. Since it was not practical to collect and analyze a large number of species of reef fish at the Atoll, we felt, for the reasons suggested above by others, that the concentrations of plutonium in mullet could be among the highest encountered in reef species and would therefore serve as useful indicator species for plutonium levels in fish commonly consumed at the Atoll.

For interspecies comparison, four snapper (2 male, 2 female), Lethrinus kallopterus, also collected on 25 June 1975 with hook and line from near reef locations between Enewetak Island and Kwajalein Island. Snapper, according to Hiatt and Strasburg (Hi 60), are hovering mid-water carnivores which remain in small schools in specific locations in the deeper water of the lagoon reef. They are secondary consumers and are representative species of the third marine trophic level at the Atoll. The 1972 plutonium concentration in dry eviscerated snapper was 80 ± 5 pCi/kg (Ne 73).

Specific tissues and organs were disected from the fish which were pooled, weighed, (wet, dry and ash) and analyzed. The ashed samples were counted on Ge (Li) detectors to determine the concentrations of gamma emitting radionuclides associated with the tissues. Each pooled sample was then radiochemically processed (Wo 71) to isolate plutonium. The dry

weight of the total pooled samples, wet/dry weight ratios, and the concentration of plutonium in the tissues are shown in Table 2. Unfortunately the mullet muscle and gill samples were inadvertently lost during processing. Recent concentration data and concentration factors of plutonium determined in mullet tissue from several islands of Enewetak Atoll (No 78b) will be used to estimate the expected concentration in the missing tissues from Kwajalein fish.

^{95}Zr was detected by gamma spectrometry only in the mullet viscera and stomach contents. The ^{95}Zr in the mullet gut probably originates from recently ingested material contaminated with fresh fallout debris from the Chinese atmospheric nuclear test conducted on 26 September 1976. The concentration in the viscera and stomach contents were 68.5 ± 13.0 and 307 ± 32 pCi/kg wet weight, respectively, on the day of collection. ^{137}Cs was above detection limits only in the snapper muscle tissue and it's concentration was 11.9 ± 1.5 pCi/kg wet weight.

Grab samples of lagoon reef sediment (0-11 cm) off Enewetak Island, Kwajalein Atoll were obtained in early 1976. The average concentration of $^{239+240}Pu$ in 9 sediment samples was 6.2 ± 1.3 pCi/kg dry weight and the mean $^{238}Pu/^{239+240}Pu$ ratio was G.032 ± 0.008. The estimated quantity of $^{239+240}Pu$ in this sediment to a depth of 11 cm, is 1.4 ± 0.5 mCi/km^2. This value falls within the range of fallout. plutonium inventories (1.4 - 3.0 mCi/km^2) that we have determined in water columns from samples collected during 1973 in the north equatorial Pacific between 4° and 16" N latitude.

Discussion

Water Concentrations

The average $^{239+240}Pu$ concentrations of the lagoon seawater, computed from Table 1, were 0.45 ± 0.21 pCi/m^3 in 1975 and 0.54 ± 0.11 pCi/m^3 in 1976. During these two years the average concentrations of ^{137}Cs were 133 ± 7 and 138 ± 7 pCi/m^3. There was no significant difference in the average concentrations during these years. In north equatorial surface seawater, average fallout concentrations of $^{239+240}Pu$ and ^{137}Cs during the two years were 0.36 ± 0.11 and 142 ± 10 pCi/m^3, respectively. The average concentration of ^{137}Cs in the lagoon is not significantly different from fallout concentrations in the oceanic surface waters which are continuously in exchange with the lagoon. The average concentration of $^{239+240}Pu$ in the open ocean is slightly lower than the lagoon mean concentration but it is within the statistical uncertainty associated with the value.

The concentrations of $^{239+240}Pu$ and ^{137}Cs in surface water collected in 1975 and 1976 at station 5 were essentially identical during the two years. Unlike the levels at station 5, the $^{239+240}Pu$ concentrations at station 1 were different. Bottom water from station 1 in 1975 and 1976 surface water contained plutonium levels which were higher than the lagoon average. Station 1 is approximately 100 yards from the remains of the Prinz Eugen, a WW II German cruiser that was used as a target vessel during the Able and Baker nuclear events held at Bikini in 1946. The vessel was towed to Kwajalein after the tests and capsized on the lagoon shelf. Fish collected near the vessel in 1947 showed trace amount of radioactive material in the organisms (Hi 62). It is possible that even after 31

years, the remains of the Eugen are still contaminated and small quantities of plutonium are continuously remobilized to the water column near this source. However, if this should be the case, the amount remobilized is not in sufficient quantities to alter the average lagoon water concentration above fallout background levels.

Since 1972 the average surface seawater fallout concentrations of $^{239+240}Pu$ in the north equatorial ocean have varied by no more than a factor of 2. The variations in surface concentrations are due to differences in the rates of new atmospheric fallout to the sea surface and to processes moving plutonium laterally and to depths in the water mass. We can assume that variations in the concentrations of plutonium no larger then those encountered in the open ocean since 1972, occurred in the lagoon water mass.

To summarize. the mean water concentration of $^{239+240}Pu$ in Kwajalein lagoon during 1975 and 1976 was slightly higher, but not outside the statistical uncertainity associated with the average global fallout levels in northern equatorial surface waters. 1975 and 1976 north equatorial surface concentrations of plutonium were similar to the levels detected during 1972. $^{238}Pu/^{239+240}Pu$ ratios measured in the 1976 water samples from the ocean and lagoon were similar in value which indicates that the radionuclides were derived from the same source. The upper 11 cm of sediment from one area of the lagoon contains a plutonium inventory within the range of the fallout inventories measured in the water columns of the north equatorial Pacific. We conclude that global fallout is the principal source of plutonium and cesium radionuclides found in the Kwajalein lagoon environment.

Fish Concentrations

The mullet stomach contents consisted of homogenized carbonate material and microbenthos while the stomach contents of the snapper contained fish parts, crustacea and some unidentified organic material. Table 2 shows a large difference between the wet/dry ratio of the' stomach contents from the two fish. The ingested food contents of these fishes are from very different components of the lagoon environment. This observation supports the description of the different feeding habits of the two species (Hi 60).

The $^{239+240}$Pu concentration associated with the mullet stomach contents was 5.0 pCi/kg dry weight. This concentration is very close to the value of the average lagoon sediment concentration (6.2 ± 1.3 pCi/kg). The average ^{238}Pu/$^{239+240}$Pu ratio in the surface sediment (0.032 ± 0.008) and stomach contents (0.020 ± 0.005) are also in good agreement. The wet/dry and ash/dry weight ratios of the stomach contents and sediment were identical. The similarity in plutonium concentrations, isotopic ratio and weight ratios indicate that the stomach contents of the mullet consists largely of benthic sedimentary material. The stomach content of the snapper, on the other hand, was found to contain a much lower concentrations of plutonium, more typical of the levels associated with the flesh of marine organisms.

^{95}Zr was detected in the viscera and stomach content samples of the mullet collected on 21 October 1976. The radionuclide was introduced to the aquatic environment sometime after 26 September 1976. Generally low ^{95}Zr concentration factors for marine fish species are measured in

laboratory experiment which shows that ^{95}Zr is poorly metabolized (Po 66). Since less than a month elapsed between the time the ^{95}Zr was introduced to the environment and the time the fish were caught, and in view of the apparent low metabolism of ^{95}Zr, it is reasonable to assume that most of the ^{95}Zr measured in the viscera sample is associated with the intestinal contents. If so, this data could be used to estimate the amount of the intestinal contents in the viscera sample which in turn allows us to estimate the concentration of plutonium associated with the internal organs associated with the disected viscera sample. We first calculate the amount of the contents in the GIT using the ^{95}Zr specific activity of the separated stomach contents. Of the 638 dry grams of viscera sample separated from the 18 fish, 326 grams of the material could account for the total ^{95}Zr measured in the viscera. The weight of the viscera without the computed gut contents is then 312 dry grams and has a wet/dry weight ratio of 4.39. The viscera plus computed gut contents contained a total of 2.92 pci of $^{239+240}Pu$. 326 dry grams of contents at 5.00 pCi/kg (stomach content concentration) should contain 1.63 pCi of $^{239+240}Pu$ leaving 1.29 pCi of plutonium associated with the viscera tissues and organs. $^{239+240}Pu$ associated only with the wet viscera is then estimated from the above arguments to be 0.94 pCi/kg. This comparative analysis shows that a significant fraction of the plutonium measured in unseparated "viscera" sample is associated with the contents in the GI tract.

Although the muscle and gill samples of the mullet were lost during processing, the concentration of plutonium can be estimated from other data. An extensive analysis was recently completed to assess plutonium and

other radionuclide concentrations in mullet collected from 13 different islands of Bikini and Enewetak Atolls (No 78b). Representative lagoon water samples were also collected for analyses. Concentration factors for plutonium in the organs and tissues of mullet were computed from the analytical results (No 78b). Excellent agreement was found between predicted and measured concentrations in fish at Bikini using only concentration factors generated from Enewetak data and the measured water concentrations at Bikini. The average concentration factor for plutonium in wet mullet bone was 139 ± 54 (No 78b) and the average concentrations of plutonium in the muscle, skin and gill tissues relative to the bone were 0.19, 2.6 and 6.2, respectively, on a dry weight basis. Using these relative values, the average measured Kwajalein lagoon seawater concentration of 0.54 fCi/l, and the wet/dry weight ratios in Table 2, we estimate that the wet Kwajalein mullet bone and skin tissue should contain $^{239+240}$Pu concentrations of 0.075 and 0.21 pCi/kg, respectively. The measured concentrations of plutonium in these tissues were 0.072 and 0.29 pCi/kg. The close agreement between the measured and predicted values indicates that there is a great deal of validity in the concept of a concentration factor and we feel justified in applying this predictive model to estimate the mullet muscle and gill concentrations at Kwajalefn. We estimate that the muscle and gill concentrations should have been 0.0034 and 0.12 pCi/kg wet weight, respectively.

Recent measured concentrations of plutonium in coastal California Rockfish (Sebastes sp.) muscle and bone (No 78c) provides additional support to these arguments and suggests further that there may be little

variation in the concentration factor for plutonium in fish muscle and bone tissues for species from different trophic levels or global locations. Rockfish from the area near the Farallon Islands collected in 1977 contained $^{239+240}Pu$ associated with the muscle and bone at concentrations of 0.008 ± 0.003 and 0.043 ± 0.004 pCi/kg wet weight respectively (No 78c). The average concentration in the upper 100 m of seawater was 0.7 ± 0.3 fCi/l (No 78c). Using the concentration factors from the Marshall Island results and the average Farallon water concentration, the predicted plutonium in the muscle and bone would have been 0.010 ± 0.004 and 0.10 ± 0.04 pCi/kg. These concentrations are in reasonable agreement with the measured values,

From the total weights of the tissues and concentrations of $^{239+240}Pu$ listed in Table 2 and the assumptions developed above, it is possible to reconstruct concentrations In any assembly of tissues and organs to compare with the 1972 concentration data.

Table 3 summarizes measured plutonium concentrations in Kwajalein Atoll reef fish from 1972 (Ne 73, Sc 75) and concentrations in the whole, eviscerated, and viscera samples collected in 1975 and 1976. The Concentration of $^{239+240}Pu$ in the 1972 dry eviscerated reef fish from Kwajalein Atoll range from 4 to 960 pCi/kg. Our measurements show concentrations in eviscerated reef fish 22 to 5000 times lower than these values. The concentration in dry eviscerated snapper is 440 times lower than the concentration measured in the 1972 snapper. Concentrations in 1972 dried viscera samples ranged 'from 9-430 pCi/kg. Our reconstructed viscera concentrations are orders of magnitude less than this range of

values. The whole 1976 mullet sample contained 1.2 pCi/kg dry, while the range in "whole" fish concentrations from 1972 ranged from 9-540 pCi/kg. Exposure to man from plutonium, by continuous daily consumption of 600 gms wet, eviscerated reef fish having a average concentration of 0.05 pCi/kg, as determined from our results, leads to a dose rate to the bone that is 0.005% of the EPA recommended guideline of 3 mrad/yr (Ep 77). Dose rates would be even less if only fish muscle or muscle and skin were normally consumed.

We have shown that Kwajalein lagoon contains levels of plutonium equivalent to global fallout concentrations and that the concentrations in mullet are predicable using relevant concentration factor data. The concentrations of plutonium recently measured in two species of reef fish with different feeding habits are order of magnitude lower than concentrations measured in 1972. We can only suggest that the earlier reported results (Ne 73) at Kwajalein were anomalous and that the dose rates to bone of man, from ingested plutonium via the marine food pathway at Kwajalein, are *closer* to 0.005% rather than 10-25% of the EPA recommended guidelines.

The concentrations of plutonium in the tissues of mullet and snapper were not as different as we would have expected from results of previous studies and models (Gu 77, Li 77, Bo 76). The estimated plutonium concentration in mullet muscle and the measured concentration In the snapper are identical within experimental error as are the concentrations associated with the bone. The skin of the snapper has associated with it slightly higher concentrations of plutonium than mullet but, on the other

hand, the estimated mullet gill concentrations are higher than levels measured in the snapper. The largest difference in concentrations are associated with the viscera samples. However, if the estimated plutonium in the intestinal contents of the mullet are subtracted from the measured total viscera concentration, only 0.94 pCi/kg wet would be associated with the mullet viscera. This is roughly a factor of two higher than the concentration associated with the snapper viscera. The concentration of plutonium associated with the contents in the snapper stomach was small. Although the intestinal tract of the snapper is small relative to the stomach, the ingested material in the intestine tract does contribute some weight to the viscera sample. If we assume this weight to be half the sample weight, as was the estimated weight for the contents in the mullet GI tract, the concentration of $^{239+240}Pu$ associated only with the snapper viscera would be equivalent to the concentration in the mullet viscera.

Concentrations of $^{239+240}Pu$ in the eviscerated samples of mullet and snapper are essentially identical whereas the average concentration in the whole mullet, on either a wet or dry weight basis, is 4 to 5 times higher than the concentration in the entire snapper. We would agree with previous studies that there is a difference in the concentration of plutonium as a function of trophic level and feeding habits only when concentrations in the entire fish are compared. However, if only concentrations in the eviscerated fish tissues are considered, the difference is insignificant.

Apparently mullet ingest more plutonium associated with their food items than the snapper; but the amounrs of $^{239+240}Pu$ concentrated in the muscle, skin or bone in fish from either the first or second trophic level

does not appear to be strongly related to feeding habits. Although there is a gradient which shows decreasing plutonium concentration in the whole fish as the trophic level of the species increases, the slope of the gradient is strongly influenced by the concentrations associated with material in the GIT and not the quantities absorbed.

Conclusions

Kwajalein lagoon contains levels of plutonium equivalent to global fallout concentrations. Concentrations of plutonium in tissues of mullet are predictable from relevant concentration factors and water concentrations. The concentration of plutonium measured in two species of reef fish collected during 1975 and 1976 are orders of magnitude lower than concentrations *measured* in similar or the same species collected during 1972 (Ne 73, Sc 75). We conclude that the expected *dose* rates to man from ingested plutonium via the marine food pathway at Kwajalein is 0.005% of the EPA Recommended guideline of 3 mrad/yr to bone (Ep 77). The magnitude of the plutonium levels reported in fish collected from Kwajalein lagoon during 1972 (Ne 73) was excessively high and the concentrations are inconsistent with the present environmental data from the lagoon.

Our data shows that concentration factors for plutonium in fish muscle and bone tissues appears to be independent of species, trophic levels and locations which leads us to believe that there is a great deal of validity in the concept of a concentration factor for estimating concentrations of plutonium in fish.

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TABLE I

CONCENTRATIONS OF $^{239+240}Pu$ AND ^{137}Cs (pCi m^{-3}) IN SEAWATER FROM KWAJALEIN LAGOON AND IN SURFACE SEAWATER AT LOCATIONS IN THE NORTH EQUATORIAL PACIFIC

Kwajalein Lagoon[a] Stat. No. and Depth Sampled (m)	Collection Date	$^{239+240}Pu$	^{137}Cs	$^{238}Pu/^{239+240}Pu$	Reference to Previously Reported Data
1-Surf.	5/10/75	0.33 (20)[b]	137(3)		No 76
1-44	5/10/75	0.87 (13)	144(5)		No 76
Z-Surf.	5/08/75	0.29 (27)	131(5)		No 76
3-Surf.	5/08/75	0.26 (24)	127(3)		No 76
3-47	5/08/75	0.33 (25)	129(3)		No 76
4-Surf.	5/08/75	0.54 (16)	129(4)		No 76
5-Surf.	6/14/75	0.52 (18)	132(4)		No 76
1-Surf.	4/17/76	0.72 (44)	133(3)		
5-Surf.	4/18/76	0.50 (12)	135(3)		
7-Surf.	4/17/76	0.53 (22)	139(3)		
7-38	4/17/76	0.57 (34)	149(3)	0.11(50)	
I-Surf.	4/17/76	0.57 (16)	132(4)	0.16(70)	
10-Surf.	10/23/76	0.37 (26)			
N. Equat. Pacific					
14°00'N180°00'W	10/72	0.35 (12)	170(12)		No 74
12°00'N170°00'W	10/72	0.44 (16)	140(14)		No 74
12°53'N173°28'E	11/73	0.22 (15)	131(4)		
05°53'N172°09'W	12/73	0.29 (66)	114(2)		
04°34'N179°02'E	12/73	0.47 (46)	122(4)		
10°26'N166°31'E	6/75	0.36 (32)	132(3)		No 76
11°16'N165°45'E	6/75	0.53 (23)	143(4)		No 76
10°00'N165°33'E	4/76	0.28 (40)	152(3)		
10°33'N164°07'E	4/76	0.39 (50)	142(4)		
10°47'N163°35'E	4/76	0.32 (15) ("soluble" fraction) 0.046(15) ("particulate" fraction)		0.16(15)	
10°00'N165°33'E	10/76	0.20 (10)	132(3)		
09°59'N165°24'E	5/77	0.25 (23)	128(3)	0.30(50)	

[a]Kwajalein station locations are shown in Fig. 1

[b]Values in parentheses are the 1 σ counting error expressed as percentage of listed value.

TABLE 2

$^{239+240}Pu$ Concentrations in Tissues of Fish from Kwajalein Atoll

	Muscle	Bone	Gill	Viscera*	Skin	Stomach Contents	Testes	Ovary
Mullet-*Crenimugil crenilabis*								
Tissue dry weight (gm)	1100	348	59.4	638	690	46.2	3.7	88.7
wet/dry weight ratio	4.00	1.78	4.27	2.77	1.67	1.21	3.07	2.70
$^{239+240}Pu$ (pCi/kg wet weight)	lost	0.072(8)	lost	1.65(3)	0.29(8)	4.13(3)	1.14(18)	0.18(27)
Snapper-*Lethrinus kallopterus*								
Tissue dry weight (gm)	243	87.4	7.3	24.4	69.3	9.0		
wet/dry weight ratio	4.12	2.07	3.49	3.87	1.69	4.57		
$^{239+240}Pu$ (pCi/kg wet weight)	0.003(30)	0.098(17)	<0.001	0.58(8)	0.46(10)	<0.003		

*Viscera samples contain: intestines, stomach, liver and other digestive organs minus the contents of the stomach.

TABLE 3

Comparative Concentration8 of $^{239+240}Pu$ in Reef Fish from Kwajalein Atoll

Year Collected	Island	Organism	Tissue	wet/dry weight Ratio	$^{239+240}Pu$ pCi/kg dry	Reference
1972	Enewetak	Convict surgeon	Eviscerated	3.54	960±80	*Ne* 73
"	"	"	Viscera	5.26	430±30	"
"	"	Damselfish	Entire	3.09	230±120	"
"	"	Parrotf ish	Viscera	2.95	410±20	"
"	Rwajalein	Convict surgeon	Eviscerated	3.54	10±1	"
"	"	"	"	3.54	11±5	"
"	"	"	Viscera	5.26	9±1	"
"	"	"	"	5.26	110±10	"
"	"	Grouper	Entire	3.37	9±1	"
"	"	Snapper	Eviscerated	3.41	80±5	"
"	"	Halfbeak	Entire	4.57	540±10	"
"	"	Rabbitfish	Eviscerated	3.91	4±1	"
"		Convict surgeon	Eviscerated		20±3	SC 75
"		"	Viscera		40±14	"
1975	Kwajalein	Snapper	Entire		0.29	
			Eviscerated		0.18	
			*Viscera		1.64	
1976	Enewetak	Mullet	Entire		1.22	
			Eviscerated		0.19	
			*Viscera		4.12	

*"Viscera" concentration is reconstructed from stomach contents and separated viscera samples which are the 1972 definition of "Viscera" sample.

Table Captions

Table 1- Concentrations of $^{239+240}Pu$ and ^{137}Cs (pCi m^{-3}) in Seawater from Kwajalein Lagoon and in Surface Seawater at Locations in the North Equatorial Pacific.

Table 2-$^{239+240}Pu$ Concentrations in Tissues of Fish from Kwajalein Atoll..

Table 3-Comparative Concentrations of $^{239+240}Pu$ in Reef Fish from Kwajalein Atoll.

Figure Captions

Fig. I.-Sampling Locations in Kwajalein Lagoon.

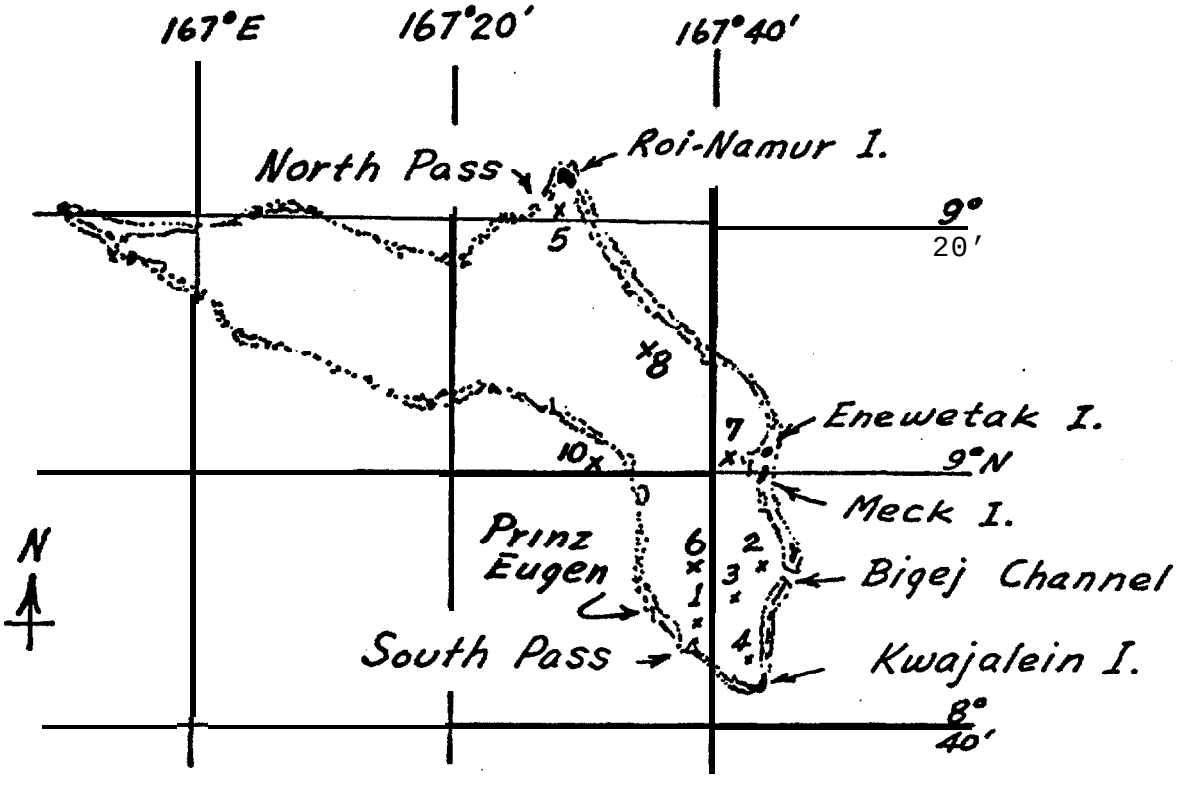

Fig. 1 Sampling locations in Kwajalein lagoon

V. E. Noshkin
Fig. 1

References

Bo 76

Bowen, V.T., Livingston, B.D., and Burke J.C., 1976. "Distributions of Transuranium Nuclides in Sediment and Biota of the North Atlantic Ocean," in IAEA Symp. Proc. Transuanium Nuclides in the Environment, IAEA, Vienna, p. 107.

Ep 77

U.S. Environmental Protection Agency, 1977. "Proposed Guidance on Dose Limits for Persons exposed to Transuranim Elements in the General Environment," EPA 520/4-77-016, U.S. Environmental Protection Agency, Wash., D.C.

Gu 77

Guary, J.C., and Fraizier, A. 1977. "Influence of Trophic Level *and* Calcification on the Uptake of Plutonium Observed, In Situ, in Marine Organisms," Health Phys. 32, 21.

He 75

Hetherington, J.A., Jefferies, D.F., and Lovett, M.B., 1975. "Some Investigations into the Behaviour of Plutonium in the Marine Environment," in IAEA Symp. Proc., Impacts of Nuclear Releases into the Aquatic Environment, IAEA, Vienna, p. 193.

Hi 60

Riatt, R.W., and Strasburg, D.W. 1960. Ecological Relationships of the Fish Fauna on Coral Reefs of the Marshall Islands, Ecol. Mono. 30, 65.

Hi 62

Hines, N.O., 1962. Proving Grounds, An Account of the Radiobiological Studies in the Pacific, 1946-1961. Univ. of Washington Press, Seattle, Wash.

Li 77

Livingston, H.D., and Bowen, V.T. 1977. "Contrasts'between the Marine and Freshwater Biological Interactions of Plutonium and Americium," in ERDA, Health and Safety Laboratory Report' HASL-315, New York, N.Y. p. I-157.

Ne 73

Nevada Operations Office, USAEC, Oct. 1973. Enewetak Radiological Survey, Vols. I-III, NVO-140, Nevada Operations Office, Las Vegas, Nevada.

Ne 75

Nevissi, A., and Schell, W.R. 1975. "^{210}Po and ^{239}Pu, ^{240}Pu in Biologic81 and Water Samples from the Bikini and Enewetak Atolls," Nature 225, 321.

No 72

Noshkin, V.E. 1972. "Ecological Aspects of Plutonium Dissemination in Aquatic Environments," Health Phys. 22, 537.

No 76

Noshkin, V.E., Eagle, R.J., and Wong, K.M. 1976. "Plutonium levels in Kwajalein Lagoon," Nature 262, 745.

No 78a

Noshkin, V.E. 1978. "Transuranium Radionuclides in Components of the Benthic Environment of the Benthic Environment of Enewetak Atoll," prepared for DOE/DBER publ. "Transuranic Elements in the Environment," TID-22800. Lawrence Livermore Laboratory Preprint, UCRL-80587.

No 78b

Noshkin, V.E., Wong, **K.M.,** Eagle, **R.J.,** and Jokela, T.A. 1978. "Plutonium Concentrations in Reef Fish at Enewetak and Bikini Atolls," In preparation.

No **78c**

Noshkin, V.E., Wong, K.M., Jokela, T.A., Eagle, R.J., and **Brunk,** J.L. 1978. Badionuclides in the Marine Environment Near the Farallon Islands, Lawrence Livermore Laboratory Rept. UCRL-52381.

PO 66

Polikarpov, G.G. 1966. Radioecology of Aquatic Organisms. **(Transl.** from the Russian by **Scripta** Technica, Ltd.) Reinhold, New York 314 p.

Ro 78

Robison, W.L., **Noshkin,** V.E., and Phillips, W.A. 1978. "Assessment of Potential Doses to Populations from the Transuranic Radionuclides at Enewetak Atoll," in preparation.

Sc **75a**

Schell, W.R., and Watters, R.L. 1975. "Plutonium in Aqueous Systems," Health **Phys.** 589.

Wi 75

Wilson, D.W., Ng, Y.C., and Robison, **W.L.** 1975. "Evaluation of Plutonium at Enewetak Atoll," Health **Phys.** 29, 599.

wo 71

Wong, **K.M.** 1971. **"Radiochemical** Determination of Plutonium in Sea Water, Sediments and Marine Organisms," *Angl.* **Chim. Acta,** 56, 355.

Wo 78

Wong, K.M., Brown, G.S., and **Noshkin,** V.E. 1978. "*A* Rapid Procedure for Plutonium Separation in Large Volumes of Fresh and Saline Water by **Mangamese** Dioxide Coprecepitation," J. Radioanal. Chem. 42, 7.